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Title: Variation in Outcomes Among 24/7 Percutaneous Coronary Intervention Centres for Patients Resuscitated from Out-of-Hospital Cardiac Arrest.

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ABSTRACT

Background: Patients treated at 24/7 percutaneous coronary intervention (PCI) centres following out-of-hospital cardiac arrest (OHCA) have better outcomes than those treated at non-24/7 PCI centres. However, variation in outcomes between 24/7 PCI centres is not well studied.

Objectives: To evaluate variation in outcomes among 24/7 PCI centres and to assess stability of 24/7 PCI centre performance.

Methods: Adult patients in the California Office of Statewide Health Planning and Development Patient Discharge Database with a "present on admission" diagnosis of cardiac arrest admitted to a 24/7 PCI centre from 2011 to 2015 were included. Primary outcome was good neurologic recovery at hospital discharge. Secondary outcomes were survival to hospital discharge, cardiac catheterization, and DNR orders within 24 hours. Data were analysed using mixed effects logistic regression models. Hospitals were ranked each year and overall.

Results: Of 27,122 patients admitted to 128 24/7 PCI centres, 41% (11,184) survived and 27% (7,188) had good neurologic recovery. Adjusted rates of good neurologic recovery (18% to 39%; p,0.001), survival (32% to 51%; p<0.0001), cardiac catheterization (11% to 49%; p<0.0001) and DNR orders within 24 hours (4.8% to 49%; p<0.0001) varied between 24/7 PCI centres. For the 26 hospitals with mean good neurologic rankings in the top or bottom tenth during 2011-2013, 14 (54%) remained in their respective tenth for 2014-2015.

Conclusion: Significant variation exists between 24/7 PCI centres in good neurologic recovery following OHCA and persists over time. Future studies should evaluate

hospital-level factors that contribute to these differences in outcomes between 24/7 PCI centres.

Key Words: Cardiac Arrest; Outcomes; 24/7 PCI centre.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is the leading cause of death from cardiovascular disease in the United States, with approximately 350,000 cases of EMS-assessed cardiac arrest in adults annually. [1] Overall survival to hospital discharge is 10.8%, with even fewer patients experiencing good neurologic recovery. [1] Among all hospitals, rates of survival to hospital discharge following OHCA vary from 14 to 42%. These differences persist even after adjustment for patient characteristics and varying across geographic regions, suggesting differences in prehospital and post-arrest care. [2, 3]

Patients treated at hospitals with percutaneous coronary intervention (PCI) capability following resuscitation from OHCA have better outcomes than those treated at hospitals without PCI capability. [4-6] To improve outcomes, regionalized care at cardiac resuscitation centres aligned with ST elevation myocardial infarction (STEMI) centres with 24/7 PCI capability; targeted temperature management for all arrest rhythms; and deferred prognostication for at least 72 hours post-arrest is recommended by current guidelines for post-arrest care. [7, 8] However, in critical illnesses similar to OHCA such as trauma [9] and stroke, [10] variation in outcomes exists even among hospitals with specialized capabilities. Whether variation in outcomes also exists specifically among 24/7 PCI centres for patients admitted following OHCA remains unknown.

Our objectives were to evaluate variation in good neurologic recovery, survival, cardiac catheterization, and “do not resuscitate” (DNR) orders within 24 hours among 24/7 PCI centres and to assess the stability of 24/7 PCI centres’ performance over time. We also sought to determine whether hospital-level rates of cardiac catheterization and

“do not resuscitate” (DNR) orders within 24 hours were associated with these outcomes. We hypothesized that hospitals would exhibit consistent variation in outcomes over time, and that hospital-level rates of cardiac catheterization and DNR orders within 24 hours would both be associated with patient outcomes at hospital discharge.

METHODS

Study Design

We conducted a retrospective cohort study involving adult patients in the California Office of Statewide Health Planning and Development (OSHPD) Patient Discharge Database. This California Committee for the Protection of Human Subjects approved this study, and our Institutional Review Board deemed it exempt from review.

Population and Setting

The OSHPD Patient Discharge Database includes all inpatient hospitalizations in California. All acute care hospitals in California are required by law to submit information on every inpatient admission. Veterans Affairs and military facilities are exempt. The data contained in the OSHPD database are very robust and widely used for research. [11-14] Variables included in the OSHPD database include demographics, payer, “do not resuscitate” (DNR) orders within 24 hours of admission, diagnosis codes (up to 25), procedure codes (up to 21), “present on admission” qualifier codes, and hospital discharge disposition. Each patient in the OSHPD Patient Discharge Database is assigned a record linkage number, which is a unique alphanumeric value based on the Social Security Number that allows multiple encounters from the same patient to be identified.

Experimental Protocol

We included all adult patients (≥18 years) in the OSHPD Patient Discharge Database with a "present on admission" diagnosis of cardiac arrest (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] 427.5) admitted from the emergency department to a 24/7 PCI centre from 1/1/2010 to 9/30/2015. A 24/7 PCI centre was defined as a hospital with 24/7 percutaneous coronary intervention (PCI) capability. Data on 24/7 PCI capability were acquired from the American Heart Association via the Cardiovascular Research Foundation website. [15] Patients with missing predictor variable(s) or outcome(s) were excluded. Detailed information regarding the data collected and data cleaning protocol has been previously published. [5]

The OSHPD Hospital Annual Utilization Data was queried for intensive care unit census days, general acute care bed days, teaching hospital status, and level 1 or 2 trauma centre status for each 24/7 PCI centre annually. We excluded 24/7 PCI centres missing one or more years of data during 2011-2015, including hospitals that opened or closed during this period.

Key Outcome Measures

Our primary outcome was good neurologic recovery at hospital discharge. Good neurologic recovery was defined as discharge to home, residential care facility, prison, jail, or another hospital for non-acute/non-skilled care; or leaving against medical advice. All other dispositions, including death, were considered not to represent good neurologic recovery. [16, 17] Our secondary outcomes were survival to hospital discharge, performance of cardiac catheterization during the index hospitalization, and DNR orders within 24 hours of admission. Survival at hospital discharge and DNR orders within 24 hours were obtained directly from the OSHPD database. Cardiac catheterization procedures were identified using ICD-9-CM codes in any of the up to 21 diagnostic codes included in the OSHPD database.

Data Analysis

Summary statistics were calculated for each variable. Continuous data were reported as the median with interquartile ranges. A mixed effects logistic regression model was fit with random intercepts for hospital to determine whether there was significant between-hospital variability after adjusting for measured patient and hospital characteristics included as fixed effects. Patient characteristics included age, sex, race, ethnicity, ventricular tachycardia or ventricular fibrillation, and insurance type. Hospital characteristics included intensive care unit census days, general acute care bed days, teaching hospital status, and level 1 or 2 trauma centre status. The models were fit both on the pooled (overall) dataset to provide the most robust overall assessment of between-hospital variation and on annual datasets to facilitate assessment of the stability of hospital relative performance. We report the variance component that reflects the normal distribution from which random effects were drawn along with the p-value for the test of the null hypothesis that the variance was zero.

Hospital-level adjusted proportions and 95% confidence intervals were calculated for each outcome. Hospitals were ranked from one to 128 each year and overall for each outcome. The difference between each hospital's highest lowest ranks during the five-year period was calculated and plotted against its overall rank in Bland-Altman plots for good neurologic recovery and survival. Spearman correlation tests were used to evaluate the correlation between hospital-level adjusted overall rates of cardiac catheterization and DNR orders within 24 hours and adjusted overall rates of good neurologic recovery and survival.

RESULTS

Of 43,909 OSHPD records with a "present on admission" diagnosis of cardiac arrest, we excluded a total of 16,787 records for a final study population of 27,122 unique patients treated

at 128 24/7 PCI centres (Figure 1). The median patient age was 66 years (55, 78) and 59% (16,078) of patients were male. Approximately one-third of patients (8,725; 32%) had a ventricular rhythm, half of whom (4,278/8,725; 49%) underwent cardiac catheterization. Approximately one-quarter (7,023/27,122; 26%) had a diagnosis of myocardial infarction, of whom 55% (3,841/7,023) underwent cardiac catheterization. Approximately one-quarter (7,188; 27%) experienced good neurologic recovery at hospital discharge. (Table 1) 24/7 PCI centres characteristics are shown in Table 2.

Between 24/7 PCI centres, unadjusted rates of good neurologic recovery ranged from 13% to 51% and rates of survival ranged from 26% to 66%. Adjusted rates of good neurologic recovery ranged from 18% to 39% ($p<0.0001$; Figure 2a). Similarly, adjusted rates of survival ranged from 32% to 51% ($p<0.0001$; Figure 2b). Adjusted rates of cardiac catheterization (11% to 49%; $p<0.0001$) and DNR orders within 24 hours (4.8% to 49%; $p<0.0001$) also varied between 24/7 PCI centres (Figure 2c-d). Adjusted rate of cardiac catheterization (correlation coefficient 0.41; $p<0.0001$; Figure 3), but not of DNR orders within 24 hours (correlation coefficient 0.034; $p=0.7$), was associated with good neurologic recovery. Similar results were seen for survival (correlation coefficient 0.46, $p<0.001$ for cardiac catheterization; and -0.13, $p=0.16$ for DNR orders within 24 hours).

For good neurologic recovery, of the 13 hospitals whose mean rankings for 2011-2013 were in the top tenth, seven (54%) remained in the top tenth when computing mean ranking from 2014-15. Similarly, seven of the 13 (54%) hospitals whose mean rankings for 2011-2013 were in the bottom tenth remained in the bottom tenth when computing the mean ranking from 2014-15. For survival, two of 14 (14%) hospitals whose mean rankings for 2011-2013 were in the top tenth remained in the top tenth when computing the mean ranking from 2014-15; 7/14 (50%) remained in the top quarter. Four of the 13 (31%) hospitals whose mean rankings for 2011-2013

were in the bottom tenth remained in the bottom tenth when computing the mean ranking from 2014-15; 9/13 (69%) remained in the bottom quarter.

DISCUSSION

Our results highlight important and stable variations in both clinical practice and outcomes after OHCA between 24/7 PCI centres in a similar geographic region after adjusting for measured patient and hospital characteristics. We found stable performance among hospitals in the top and bottom tenth for adjusted rates of good neurologic recovery and survival, which aligns with a similar study in trauma centres which showed recent performance predicts future performance. [9] Our results also suggest that additional unmeasured factors are contributing to patient outcomes. Differences in both clinical care and organizational culture between hospitals have been associated with both mortality and disease-specific outcomes in other diseases, [18-21] and may have a similar influence in OHCA.

In our study, cardiac catheterization rates were associated with both survival and good neurologic recovery. Notably, our data showed a linear relationship between hospital-level adjusted rates of cardiac catheterization and good neurologic recovery, without evidence of "overuse" of cardiac catheterization being associated with poorer outcomes (Figure 3). These findings align with previous data showing an association between early PCI and lower short- and long-term mortality and better neurological outcomes. [22-25] While cardiac catheterization and PCI may directly cause this increase in favourable outcomes by restoring coronary flow in patients with critical coronary lesions, [23, 26] they may also be a surrogate marker for more aggressive post-arrest care. Other post-arrest interventions associated with improved outcomes in patients resuscitated from OHCA include targeted temperature management, [16, 25] seizure

detection, [27] and avoidance of hyperoxia. [28] Availability and implementation of these interventions may also vary between 24/7 PCI centres.

The overall rate of cardiac catheterization and the rate of cardiac catheterization in patients with myocardial infarction following OHCA in our study was lower than expected given current American Heart Association/American College of Cardiology guidelines. Current guidelines provide a Class I recommendation for emergent coronary angiography in OHCA patients with suspected cardiac aetiology of arrest and ST elevation on their electrocardiogram and a Class II recommendation for emergent coronary angiography in similar patients without ST elevation on their electrocardiogram. [7] Notably, the 23% overall rate of cardiac catheterization was stable over the five-year period [data not shown] despite many local emergency medical services agencies in the state implementing protocols for the transport of OHCA patients with prehospital return of spontaneous circulation to 24/7 PCI centres. While these patients may benefit from other resources such as critical care and targeted temperature management available at 24/7 PCI centres, our data suggest the potential benefits of cardiac catheterization are not fully realized in our population. Public reporting of PCI outcomes may also influence the decision to perform cardiac catheterization in post-OHCA patients, as it is difficult to perform adequate risk adjustment for cardiac arrest in these models. [29, 30]

Interestingly, in our study, rates of DNR orders within 24 hours – which varied nearly ten-fold between hospitals - were not associated with survival or good neurologic recovery at hospital discharge. The variation we found aligns with prior studies showing variation between hospitals in DNR ordering practices, [31-33] but our lack of association with outcomes contrasts with prior studies focused on in-hospital cardiac arrest, [32, 33] severe sepsis, [34] and severe traumatic

brain injury. [31] Lack of association with outcomes may indicate that physicians are appropriately using early DNR orders in patients with underlying terminal illnesses or clearly non-survivable conditions. [7] It may also indicate that physicians are appropriately interpreting DNR orders as a directive to not initiate cardiopulmonary resuscitation in the event of a recurrent cardiac arrest and not a directive to withhold other treatments or interventions, in contrast to prior studies. [32-34]

The observed variation in cardiac catheterization and early DNR orders may represent differential uptake of evidence-based practices at 24/7 PCI centres. DNR orders within 24 hours may represent early prognostication and DNR order discussions with families, in contrast to current guidelines which recommend deferring prognostication until 72 hours for most patients resuscitated from OHCA. [7] Prior studies identified limited awareness of recommended practice, disagreement with the supporting literature, lack of institutional protocols, and limited equipment and personnel resources as reasons for low adherence to evidence-based practices in temperature management following OHCA, [35] and these reasons likely apply to cardiac catheterization and other aspects of post-OHCA care. Future work is needed to determine which aspects of variation in clinical care affect patient outcomes and should be targeted in future interventions to improve post-OHCA care.

Organizational culture, defined as a set of shared values, beliefs, and assumptions within an organization that influences how people within that organization behave, [36] affects clinical care decisions. [37] Organizational culture is associated with performance in disease processes that overlap with OHCA, including acute myocardial infarction [19, 21, 38, 39] acute ischemic stroke, [40] and critical illness. [41] Clinicians' perception of futility in the care of patients

resuscitated from OHCA was a barrier to implementation of specialized post-OHCA care at several hospitals [37] and may contribute to the variation in outcomes seen in our study. Future studies should evaluate differences in organizational culture between 24/7 PCI centres with differential outcomes.

LIMITATIONS

Our study has several limitations. Our analyses were limited by the data contained in the OSHPD database. We identified patients using a “present on admission” code for cardiac arrest, and we were unable to independently verify the accuracy of ICD-9-CM codes in the hospital electronic medical records at all 24/7 PCI centres statewide. However, the number of patients we included from the OHSPD database with a “present on admission” code for cardiac arrest (ICD-9-CM 427.5) is consistent with the expected number of OHCA admissions based on existing literature. [2, 42] We used discharge disposition as a surrogate for good neurologic recovery. Our classification aligns with the definitions of good neurologic recovery used in previous studies of post-cardiac arrest patients [43, 44] and correlates with the Cerebral Performance Category score. [45, 46] We were unable to adjust for prehospital arrest characteristics that are associated with outcomes. [47, 48] We were also unable to evaluate the relationship between outcomes and certain procedures such as targeted temperature management and electroencephalogram, as very few patients [7.3% (1,987/27,122) and 3.5% (962/27,122), respectively] were reported to have received them.

CONCLUSION

Rates of good neurological recovery, survival, cardiac catheterization and DNR order

within 24 hours of admission after OHCA vary considerably among 24/7 PCI centres in California. Overall rate of cardiac catheterization following OHCA was low, with 4.5-fold variation between 24/7 PCI centres. Future studies should evaluate additional, unmeasured factors in patient care and organizational culture that may contribute to these important differences in outcomes between 24/7 PCI centres.

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LEGENDS TO FIGURES

Figure 1. Flow diagram of OSHPD study population.

Figure 1 Legend. OSHPD = Office of Statewide Health Planning and Development; PCI = Percutaneous coronary intervention.

Figure 2a-d. Variation between 24/7 PCI centers in good neurologic recovery at hospital discharge (2a), survival at hospital discharge (2b), performance of cardiac catheterization (2c), and “do not resuscitate” orders within 24 hours (2d).

Figure 3. Correlation between adjusted rates of cardiac catheterization procedures and good neurologic recovery among 24/7 PCI centers.